From History to Clinical Practice: The Journey of Cosmetic Bone Lengthening: A Comprehensive Literature Review

Majdi Hashem, MD*

ABSTRACT

Cosmetic bone lengthening has evolved significantly over the years, addressing skeletal deformities and dwarfism resulting from various conditions, and even for aesthetic purposes. This literature review provides an in-depth overview of the historical background, fundamentals, challenges, outcomes, complications, and clinical applications of cosmetic bone lengthening. The practice dates back to the early 1900s with innovations by pioneers like Alessandro Codivilla and later, Professor Gavril A. Ilizarov, who developed the Ilizarov technique. The fundamental principle of distraction osteogenesis underpins these procedures, involving gradual bone elongation to promote new bone formation. Various techniques, including the Ilizarov fixator, Lengthening Over Nail (LON), and implantable lengthening nails, have been utilized, each with specific indications, outcomes, and complications. Studies have reported high patient satisfaction and significant functional improvements, although complications such as infections, nerve injuries, and joint stiffness are common but generally manageable. Ethical considerations and the need for psychological assessment before surgery are emphasized due to the profound impact on patients' lives. Despite the risks, cosmetic bone lengthening has shown favorable results in improving height, self-esteem, and quality of life, suggesting its potential benefits outweigh the challenges when performed with appropriate care and ethical considerations.

Keywords: Bone Lengthening; Bone surgery; Cosmetic; Limb lengthening; Orthopedics; Review

INTRODUCTION

Bone lengthening has been performed over the years for treating skeletal deformities and/or dwarfism resulting from various conditions such as infections, tumors, trauma, or congenital abnormalities, and even for aesthetic purposes [1,2]. Distraction osteogenesis by the Ilizarov leg lengthening method has been utilized for constitutional short-stature individuals wanting to increase their height [3]. This method is also known as symmetrical extended limb or cosmetic leg lengthening [4].

A height of 2 standard deviations (SDs) or more below the average height of a group of comparable pubertal stage, gender, and age are considered short stature [5-7]. In our contemporary societies, there is considerable importance on attractiveness and physical appearance [6]. As a result, short-stature individuals may suffer from psychosocial conditions that begin earlier in childhood or adolescence [8,9]. Cosmetic leg lengthening procedures enhanced patients' self-esteem and social skills [10]. Patients undergoing this procedure report positive outcomes; most consider their height normal and become satisfied due to a considerable improvement in their personal and professional lives [10].

While there are some non-surgical methods of cosmetic bone lengthening, such as the use of medications to help bones grow, most of these are still in their infancy and thus have not been a part of medical practice. A few treatments for growing bones with growth hormones and bone-stimulating agents exist but have very limited application for any significant cosmetic lengthening in adults. Generally, they address medical conditions, such as growth deficiencies in children, more so than cosmetic ones. Besides, they cannot be widely used because of their side effects, like hormonal imbalance and abnormal bone development, that raise a number of questions regarding safety.

Cosmetic bone-lengthening surgery, like limb lengthening, can have serious economic implications due to the expense and long recovery period. Depending on the complexity, expertise of the surgeon, and geographical location, these surgical practices range from tens to hundreds of thousands of dollars. Besides the direct medical costs, rehabilitation, physical therapy, follow-up care, and complications might further add to burdensome costs for the patients. Besides this, the prolonged convalescence is responsible for the loss of wages and total productivity, thus furthering the economic burden.

This literature review aims to deliver an exhaustive overview concerning the historical background, fundamentals, challenges, outcomes, complications, and clinical applications of cosmetic bone lengthening; hence, it may advance a better understanding of the benefits and concerns associated with the procedure.

HISTORICAL BACKGROUND

The basics of bone lengthening go back to the beginning of the nineteenth century when initial lengthening limbs efforts aimed to address shortening caused by post-trauma [11,12]. Clayton Parkhill, a surgeon who practiced in Denver, Colorado, in the early 1900s, developed the first effective external fixator that could be utilized in various clinical scenarios [12]. Overall, the outcomes of this procedure were positive [11].

In 1903, the first surgeon to use skeletal traction for limb lengthening was the Italian surgeon Alessandro Codevilla, who practiced in Bologna [13,14]. Because of this contribution, he is recognized as the "Father of Modern-Day Leg Lengthening" [15]. Despite this, many severe complications occurred after this operation [16], for instance, a prolonged hospital admission during the lengthening operation [11]. In 1913, Louis Ombrédanne lengthened a femur by an additional 4 cm through gradual elongation at a rate of 5 mm per day [17]. He used an external fixator with one pin placed above and another below the osteotomy

* Department of Surgery
Faculty of Medicine, Imam Mohammad Ibn Saud Islamic University
Riyadh, Saudi Arabia.
Email: mahashem@imamu.edu.sa

[17]. In 1921, Vittorio Putti, a student of Codivilla, initially documented the technique of extending bone length through gradual distraction following osteotomy [15,18]. Putti process no longer necessitated ongoing hospitalization [11]. In 1927, Leroy Abbott had initially described a lengthening method utilizing an external fixator that was more stable [19]. In 1939, Abbott and John Saunders provided an exhaustive description of Abbott's lengthening method [20].

In 1951, orthopedic surgeon Professor Gavril A. Ilizarov began his influential work, setting the foundation for modern methods of extending bone length [21,22]. Through the 1950s and 1960s, Ilizarov introduced a creative technique using circular external fixators and established principles of distraction osteogenesis [23]. In the early 1980s, his method gained widespread adoption and became the leading technique for lengthening limbs [23]. It has been utilized for pathological conditions and psychological and cosmetic indications [1,2,24-26].

Heinz Wagner, a surgeon from Germany, concisely brought attention to the rapid distraction and extensive soft tissue release method in the Western community from the early 1970s to the mid-1980s [15,27,28]. Besides, Wagner also introduced the mono-lateral external fixator in 1978 [28]. Latterly, the Taylor Spatial Frame, a hexapodal computer-aided circular frame, gained popularity [22]. Recent years have significantly shifted towards implantable nails with controlled lengthening mechanisms; these include the PRECICE, Phenix, intramedullary skeletal kinetic distractor, Albizzia, Fitbone, and the Bliskunov telescopic nail [29]. Nevertheless, Ilizarov's principles continue to be the basis for all operations of bone-lengthening [22].

Fundamentals, Challenges, Outcomes, and Complications of Cosmetic Bone-Lengthening

The fundamental principle of bone-lengthening relies on a biological process known as distraction osteogenesis. Gradual compression of the . It initiates the formation of new bone tissue between the two bone segments [32]. Bone lengthening biology can be divided into three phases [22]: the latency phase, the distraction phase, and, finally, the consolidation phase. The latency phase, which follows the osteotomy, is biologically like the inflammatory phase of fracture healing [35,36]. Granulation tissues form a soft callus during this phase [35]. Throughout the distraction phase, the callus gradually stretches at a specific frequency and speed until the intended elongation is attained [37]. Then, the distraction gap undergoes mineralization during consolidation phase [38]. This phase typically lasts around 4 weeks for every centimeter of lengthening [the most extended phase] and continues until completely restoring the bone's mechanical strength [39,40].

There were different techniques used in cosmetic limb lengthening surgeries, including implantable lengthening nails (ILN), lengthening and then nail (LATN), lengthening over nail (LON), and Ilizarov external fixation frames [25,41-46]. However, attention to psychological and ethical issues is mandated in cosmetic bone lengthening for both short and normal-height individuals [22]. Before proceeding with surgery, all patients must have a psychiatric assessment and thorough psychological evaluation [22,47]. Therefore, participating in multiple counseling sessions and discussions with individuals who have undergone similar treatment is recommended [48]. Additionally, public health systems or medical insurance do not provide refunds for any cosmetic surgery type, which could be a significant obstacle for individuals seeking cosmetic bone lengthening [10].

Cosmetic bone lengthening procedures have shown favorable results [25,42,46,49,50]. Regarding increasing height, studies indicate that patients usually express high satisfaction due to the improvement in height [51], which often leads to enhanced self-esteem and social confidence [10]. In addition, these operations showed positive effects on patients' daily lives and sports activities and maintaining joint mobility. Within two years after the procedure, patients may predict to regain the capacity to engage in light sports activities and carry out everyday tasks [41]. Cosmetic bone lengthening also provides significant psychological benefits, like reducing body image problems and socialization difficulties [52]. Overall, it would improve the quality of life after surgery [22].

Although cosmetic bone lengthening has shown positive results, it is usually associated with many complications, which could be severe [46]. The size of the regenerated area and the reason for the shortening determine the occurrence of complications [22]. Utilizing external fixators for lengthening procedures can result in multiple complications, such as delayed return to normal activities [53], joint pain and stiffness, muscle spasms, and pin site infections [54]. There is also a risk of refractures after removing the external fixator [55]. Nevertheless, intramedullary limb lengthening has arisen as a reasonable alternative to external fixation with lower complication rates at a higher cost, making it entirely adorable to many patients [56].

Table 1. Cosmetic bone lengthening complications and complications management

Complications	Incidence	Management
Pin site infections	Common, particularly with external fixators (May affect all treated patients [22])	Oral antibiotics [58-60] Enhanced wound care [59]
Nerve injury [51] (like Nerve palsy)	Nerve palsy is common [61]	The surgical solution for a tight compartment is performing an immediate fasciotomy and Slowing or halting the elongation process results in the restoration of neurapraxia [62-65]
Joint stiffness	Common complication in most studies [66]	Bracing for soft tissue tension management and intense physiotherapy [67-69]
Leg length discrepancy	N/A	Reapplication Ilizarov apparatus [70]
Malunion or nonunion	Rare [71]	Employment of bone-graft substitutes to fill defects and for bone repair, use of bone transport or bone grafts, stabilization of fixation, and restoration of alignment [72]
Poor regenerate formation	Rare in young persons [27]	Alternative compression distraction cycles [73]

N/A, not available.

Table 2. Summarizes studies on cosmetic bone lengthening

Cosmetic indication	Sample size	Bone segment	Technique	Lengthening achieves	Patient satisfaction	Functional improvement	Complications	Reference
Forearm lengthening	12	Radius and Ulna	Ilizarov technique	2–13 cm	High	All patients cosmetically and functionally improved	11 complications	Villa et al 1990 [74]
Leg lengthening for short stature	60	Bilateral lower legs	Improved bone lengthening technique	5–10 cm Mean 6.8 cm	High	Normal gaits and intense activities were regained.	No severe complication	Ruan et al 2002 [75]
Multiple congenital brachymetatarsia	5	Metatarsal bones	One-stage combined shortening and lengthening	Achieved nearly normal parabola	High	All patients regained a nearly normal parabola	No complications were reported	Kim et al 2004 [76]
Bilateral leg lengthening	54	Tibia	Hybrid advanced fixator	5–11 cm Mean 7.0 cm	High	Excellent (90.7%) and Good (9.3%)	No major complications	Catagni et al 2005 [25]
Lower limb lengthening	131	Bilateral lower limb	Ilizarov external fixator	Mean 6.9 cm	High	High	Soft tissue and bone-related complications	Novikov et al 2014 [46]
Leg lengthening for short stature	50	Lower limb	Ilizarov ring external fixator (the maximum stability technique)	4–11 cm Mean 6.9 cm	All patients except one were satisfied	Excellent outcomes were achieved in 49 patients	All complications were successfully treated without affecting the outcome or patient satisfaction.	Elbatrawy & Ragab 2015 [42]
Arm lengthening	1	Humerus	Monorail unilateral external fixator	9 cm	Satisfied	Cosmetically and functionally acceptable	No complications	Agrawal et al 2015 [77]
Bilateral leg lengthening	63	Bilateral leg	Hybrid advanced fixator	5–11 cm Mean 7.2 cm	High	High	No major complications	Guerreschi & Tsibidakis 2016 [10]
Lower limb lengthening	32	Femur or tibia	LON	Mean 7.5 cm	29 of patients were very satisfied	High	34 complications were reported	Kocaoglu et al 2017 [44]
Stature lengthening	795	Femur, tibia, or both	Classic 3- or 4-ring Ilizarov fixator (267 patients) LON (253 patients) ILN (63 patients)	Mean 6.7 cm	High	Favorable outcomes	Low rate of major complications	Marwan et al 2020 [51]
Bilateral leg lengthening	9	Femur or tibia	Intramedullary nail lengthening	Mean 8.7 cm	High	Favorable outcomes	Proximal locking screw runaway, quadriceps contracture, and insufficient bone regeneration	Havitcioglu et al 2020 [53]

LON, lengthening over nail; ILN, implantable lengthening nails.

Ensuring mechanical stability is essential in cosmetic bone-lengthening to promote successful bone regeneration and minimize complications. This procedure, frequently utilizing instruments such as intramedullary nails or external fixators, depends on the progressive process of distraction osteogenesis, in which the bone is incrementally separated to facilitate the growth of new bone [57]. Ensuring stability entails the maintenance of correct alignment, the management of soft tissues, and the initial limitation of weight-bearing to prevent any disruption to the healing process. To ensure optimal outcomes, it is crucial to regularly evaluate, provide physical therapy, and provide careful post-operative care [57]. These measures are necessary to minimize complications such as nonunion, infection, or device failure, while still achieving successful length gain without compromising functionality.

Previous studies reported many complications related to cosmetic limb lengthening, such as leg length discrepancy, joint stiffness, nerve injuries, and pin site infections [25,41-46]. Nevertheless, these complications can be managed (Table 1). The safety of the patients should have more of a priority than additional length achievement [46].

Clinical Applications

According to the literature, multiple techniques were used for cosmetic bone lengthening, each associated with specific indications, outcomes, and complications [10,25,42,44,46,51,53,74-77] (Table 2). Techniques like the Ilizarov fixator, LON, and lengthening with intramedullary nails have been used for indications like cosmetic increase in stature, congenital brachymetatarsia, forearm lengthening, and arm lengthening. The average lengthening reported is between 2 to 13 cm. Considerable benefits for cosmetic bone lengthening were documented, like high patient satisfaction, significant functional improvement in normal gait, recovery from intense activities, improved self-esteem, and enhanced social capabilities. However, studies have reported a wide range of complications, but generally, it is manageable.

Villa et al. (1990) studied forearm lengthening in 12 patients using the Ilizarov technique, achieving 2–13 cm of lengthening with high satisfaction despite 11 complications. Ruan et al. (2002) reported on 60 patients undergoing leg lengthening for short stature, achieving a mean lengthening of 6.8 cm with high satisfaction and no severe complications. Kim et al. (2004) found that all 5 patients with congenital brachymetatarsia regained a nearly normal parabola without any complications. Catagni et al. (2005) documented high satisfaction in 54 patients with bilateral leg lengthening using a hybrid advanced fixator, achieving a mean lengthening of 7.0 cm with no major complications. Novikov et al. (2014) observed high satisfaction in 131 patients undergoing lower limb lengthening with the Ilizarov fixator, despite soft tissue and bone-related complications. Elbatrawy & Ragab (2015) reported excellent outcomes in 49 out of 50 patients undergoing leg lengthening with the Ilizarov ring external fixator, with all complications successfully treated. Agrawal et al. (2015) achieved satisfactory cosmetic and functional results in a single case of arm lengthening using a monorail unilateral external fixator, with no complications. Guerreschi & Tsibidakis (2016) noted high satisfaction and no major complications in 63 patients undergoing bilateral leg lengthening with a hybrid advanced fixator. Kocaoglu et al. (2017) found high satisfaction in 32 patients undergoing lower limb lengthening using the LON technique, despite 34 complications. Marwan et al. (2020) documented favorable outcomes with a low rate of major complications in 795 patients undergoing stature lengthening with various techniques, achieving a mean lengthening of 6.7 cm. Finally, Havitcioglu et al. (2020) reported favorable outcomes in 9 patients undergoing bilateral leg lengthening with intramedullary nail lengthening, despite some complications like proximal locking screw runaway and quadriceps contracture.

CONCLUSION

Cosmetic bone lengthening is a combination of traditional surgical methods with new technology. Advancements in developing surgical techniques and devices, such as the Ilizarov device, the Taylor spatial frame, and intramedullary nails, have enhanced precise and controlled lengthened bones. According to clinical studies, most patients significantly improve height, quality of life, self-esteem, and function. However, there are many risks associated with cosmetic bone lengthening, like infection, nonunion or malunion, soft tissue complications, and others. Still, most of the complications are controllable with reasonable care and monitoring. It also presents ethical challenges; therefore, ethical implications must be considered to optimize the application of this procedure. Finally, further improved imaging, minimally invasive application, increasing biological modifications, and an additional evolution trend toward patient-specific customization may improve outcomes from cosmetic bone lengthening.

Author Contributions

M.H. supervised this study in terms of methodology, statistical analysis and drafting. Besides, he is responsible for conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; has agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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